

## **JSC/EC5 U.S. Spacesuit Knowledge Capture (KC) Series Synopsis**

**All KC events will be approved for public using NASA Form 1676.**

*This synopsis provides information about the Knowledge Capture event below.*

**Topic:** Apollo Lunar Surface Operations and EVA Suit Issues

**Date:** September 12, 2012      **Time:** 12:00-1:30 pm      **Location:** JSC/B5S/R3102

**DAA 1676 Form #: 29309**

A PDF of the presentation is also attached to the DAA 1676 and this is a link to all lecture material and video: <\\js-ea-fs-03\pd01\EC\Knowledge-Capture\FY12 Knowledge Capture\20120912 Scheuring Apollo EVA Ops\For 1676 Review and Public Release>

\*A copy of the video will be provided to NASA Center for AeroSpace Information (CASI) via the Agency's Large File Transfer (LFT), or by DVD using the USPS when the DAA 1676 review is complete.

### **Assessment of Export Control Applicability:**

This Knowledge Capture event has been reviewed by the EC5 Spacesuit Knowledge Capture Manager in collaboration with the author and is assessed to not contain any technical content that is export controlled. It is requested to be publicly released to the JSC Engineering Academy, as well as to CASI for distribution through NTRS or NA&SD (public or non-public) and with video through DVD request or YouTube viewing with download of any presentation material.

**Presenter:** Richard Scheuring

**Synopsis:** The potential risk of injury to crewmembers is inherent in aggressive surface activities, whether they be Moon-, Mars-, or asteroid-based. In December 2005, the Space Medicine Division at JSC requested a study to identify Apollo mission issues that had an impact to crew health or performance or both. This talk focused on the Apollo EVA suit and lunar surface operations concerning crew health and performance. There were roughly 20 recommendations from this study of Apollo for improving these two areas for future exploration missions, a few of which were incorporated into the Human Systems Integration Requirements (HSIR). Dr. Richard Scheuring covered these topics along with some of the analog work that has been done regarding surface operations and medical contingencies.

**Biography:** Dr. Richard Scheuring grew up in Chicago, Illinois, focused on track and field, and dreamed of becoming an Olympic athlete. This drive earned him an athletic scholarship to Eastern Illinois University where he earned bachelor of arts in psychology and competed in a decathlon. But after three-and-a-half years of intense competition and an unfortunate series of devastating injuries, his dream to compete in the Olympics was over. Scheuring took his Olympic-sized desire and passion and focused on becoming a doctor of osteopathic medicine at Chicago College of Osteopathic Medicine. He then ran his own family practice, sports medicine clinic in Illinois for several years before learning of the aerospace medicine profession. Realizing he could possibly combine his childhood love for space exploration with his medical career, Scheuring completed an aerospace medicine residency and earned a master of science in

aerospace medicine at Wright State University. After the September 11 attacks, Scheuring signed up to be a U.S. Army Reserve flight surgeon. He subsequently served in Iraq as a battalion flight surgeon for the 171st General Support Aviation Battalion (GSAB) in Camp Taji, just north of Baghdad where he had over 100 hours of combat flying. Later he discovered the required training for this was the final puzzle piece needed to reach his dream job, serving as a NASA flight surgeon at JSC. As of 2012, he was serving as the team lead for musculoskeletal-sports medicine and rehabilitation at NASA.

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# ***Apollo Medical Operations Project: Recommendations for EVA and Lunar Surface Operations***

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<sup>2</sup>Universtiy of Texas Medical Branch/Wyle Laboratories

<sup>3</sup>University of Chicago Medical School



## ◆ Introduction

- This study followed a request made by the Medical Operations Branch, Space Medicine Division of NASA-JSC in December, 2005.
- The objective was to identify problems that occurred during the Apollo missions relevant to medical operations that had an impact on crew health or performance or both:
  - Validate and refresh our systems knowledge to make sure we get it right the second time around
  - Implications for the explorations effort
  - **Not** a review of information contained in the *Biomedical Results of Apollo*



## ◆ Goals

- Develop or modify medical requirements for new vehicles.
- Create a centralized database.
- Take this new knowledge to the different directorates participating in the exploration effort.



# ***Apollo Medical Operations Project***

## ◆ **Work Strategy**

- Background research:
  - Identify specific problems in each area.
  - Explain how these problems impacted the crew.
  - Identify whether these problems were fixed or not.
  - Develop a database of questions.
- Face-to-face meeting with the Apollo crewmembers



# ***Apollo Medical Operations Project***

## ◆ **Methods**

- Face-to-face meeting on 7, -8, & -9 June 2006:
  - Days 1 & 2 closed sessions
  - Day 3 open session:
    - Apollo flight surgeons
- Post-summit:
  - Allowed astronauts who were not able to attend the summit to participate



## ◆ Methods

- Review of Apollo resources pertaining to Medical Operations\*
  - Sources of data:
    - ❑ *Apollo medical mission debriefs*
    - ❑ *Apollo flight surgeon logs*
    - ❑ *Apollo biomedical engineer (BME) logs*
    - ❑ Apollo mission commentaries
    - ❑ Apollo mission reports (11-17)
    - ❑ Apollo lunar surface journals (11-17)
    - ❑ Preliminary science reports (11-17)
    - ❑ Apollo lecture series
    - ❑ Personal communications



\*Crew logs, crew questionnaires, and air-to-ground communications unavailable



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Video/Multimedia

Past Program Links

Services/Capabilities

HEFD Links

HH&P How Do I?

Education and Outreach Community


Education and Outreach is embedded in multiple projects and communities in the Habitability and Environmental Factors Division. This webpage provides a window into the education and outreach activities and communication materials.

Past Program Educational Series Videos

Date	Title	Presenters	Time
8/26/2005	Internal Volume/Stowage - Langdoc and Bond	Langdoc, Bond	Multiple Videos
10/7/2005	Radiation Lessons from Apollo	Bailey, Hardy, Rose, White, Weyland	Multiple Videos
10/14/2005	Guidance and Controls	Aaron Cohen	01:15:00
12/9/2005	Lunar/Surface Ops	Alan Bean	
1/27/2006	EVA Hardware and Life Support	Ed Smylie	01:35:14
3/10/2006	Apollo Crew Compartment and EVA	Jerry Goodman	
3/24/2006	Space Experience	John Aaron	01:41:51
3/31/2006	Part Two: Apollo Crew Compartment and EVA	Jerry Goodman	01:36:05
4/14/2006	Part One: Apollo vs. NASA Now - Walt Cunningham	Walt Cunningham	38:39
4/14/2006	Part Two: Apollo vs. NASA Now	Walt Cunningham	45:21
6/28/2006	Mission Operations, Apollo Today	John O'Neill	58:53
7/21/2006	Apollo: Management Lessons & Rewards	Harrison "Jack" Schmitt	01:32:23
10/16/2006	Medical Challenges of the Apollo Era	Chuck Berry, M.D.	58:53
12/1/2006	Thornton's Hardware Project List	Dr. William Thornton	58.33
6/15/2007	Apollo Medical Operations Project Briefing		
7/24/2007	CEV Habitation Accommodations Systems		

Schedule an SF Tour

Schedule a tour of the SF facilities. For more information view the [SF Tour Webpage](#). To visit multiple SF facilities contact Rhonda Rose, the SF Division Contact.



Education and Outreach Highlights

Date Reported	Headline
8/30/2012	Integrated Immune – SMO-015: A revision of a manuscript entitled Reactivation of Latent Viruses Is Associated with Increased Plasma Cytokines in Astronauts (S. K. Mehta, B. E. Crucian, R. P. Stowe, R. J. Simpson.,C. M. Ott, C. F. Sams and D. L.
8/9/2012	HH&P Laboratories and Facilities conducted tours and briefings to Glenn Research Center's NASA Academy
8/2/2012	M. Perchonok spoke with K. Segal at CNN who writes the most read CNN Blog Eatocracy
8/2/2012	A food lab and microbiology lab tour, space food briefing and small food tasting was provided to the top US robotics team from the 2012 First Lego League World Festival Championship
8/1/2012	M. Cooper conducted a National Public Radio interview for the broadcast



# ***Apollo Medical Operations Project***

## ◆ **Apollo 7-17 Categories**

1. **EMU/EVA suit**
2. **Lunar surface operations**
3. In-flight illnesses/medical kit/medications
  - Bioinstrumentation
4. Environmental (vehicle)
5. Radiation
6. Exercise
7. Food/nutrition
8. Performance/human factors
  - Crew schedule
9. Launch/re-entry/recovery
10. Flight surgeon-crew interaction



***Apollo 11 Launch***



# ***Apollo Medical Operations Project***

## ◆ **Results**

- Development of MS Access® database with 655 records of categorical data pertaining to the Apollo 7-17 missions
- 236 pages of responses to 280 questions from the face-to-face meeting
- Initially 14 of 22 (64%) participation formed the basis of the Apollo Medical Operations recommendations



***Apollo Medical Operations Summit, 7-9 June, 2006***



# Apollo Medical Operations Project

Input from 14 of 22 astronauts (summit and post-summit)	64%		
<b>POST-SUMMIT Responses only</b>	<b># of Questions</b>	<b>Post-Summit # of Responses</b>	<b>Post-Summit Response Rate</b>
<b>EMU/EVA Suit</b>	<b>63</b>	<b>30</b>	<b>8%</b>
<b>Lunar Surface Ops</b>	<b>36</b>	<b>20</b>	<b>9%</b>
In-flight Illnesses/Medications	16	24	25%
Medical Kit	3	4	22%
Bioinstrumentation	3	5	28%
Environmental Impacts	35	75	36%
Radiation	5	4	13%
Exercise	20	33	28%
Food Nutrition	28	76	45%
Performance/Human Factors	16	48	50%
Crew Work-Rest Schedules	10	30	50%
Launch Recovery	34	121	59%
Flight Surgeon Crew Interaction	2	7	58%
General Questions	14	31	37%
<b>Totals</b>	<b>285</b>	<b>508</b>	





# Apollo Medical Operations Project

## ◆ EMU/EVA Suit

- Comments:
  - The most fatiguing part of EVA tasks was repetitive gripping
  - *“Efficiency was no more than 10% of the use of the hand”*
  - Fingernails being pulled back (onycholysis)
  - Skin being abraded from the top of the knuckles
  - The crew experienced no trauma in training, though muscle fatigue occurred



Photo courtesy Drs. Jeff Jones and Sam Strauss



# Apollo Medical Operations Project

## ◆ EMU/EVA Suit

- Recommendations:

- **Improve glove flexibility, dexterity, fit:**

- Gloves should be custom designed for each crewmember that incorporate mechanical closure for gripping
    - Look into a wrist seal and depressurized glove
    - Power-assisted glove for repetitive manual (skilled) tasks
    - Robotic assistants for repetitive menial tasks
    - Glove liners should be worn





# Apollo Medical Operations Project

## ◆ EMU/EVA Suit

- Recommendations for the glove:
  - The goal is getting as close to normal dexterity and use of the hands as possible.
  - The lower the pressure (in the suit), the less strength it takes to manipulate.
  - Reduce glove bulk by making bladder thinner.
  - Severe chafing in the glove can be eliminated using silk glove liners.
  - Possibly a robotic hand could be used or a mechanically augmented glove.





# Apollo Medical Operations Project

## ◆ EMU/EVA Suit

- Recommendations:
  - Reduce the mass of the suit by a factor of two
  - Increase general mobility by a factor of four
    - Primarily at the knee joint
      - “*Bending the knee was difficult in the suit. We need a better [more flexible] knee joint.*”







# Apollo Medical Operations Project

## ◆ EMU/EVA Suit

- Recommendations
  - Lower suit center of gravity
    - *“Don’t make moving the CG your primary priority. Move the CG only if it becomes convenient to do so while taking care of other issues like reducing the mass of the suit, etc.”*





# Apollo Medical Operations Project

## ◆ EMU/EVA Suit

### ● Recommendations

— Improve peripheral vision in the suit:

- Design the helmet to allow you to see your feet.
- You would always have to turn your body to see.
- The Navy deep-sea diving helmet with rotating neck ring is a good option and should be considered in the new suit design.





# Apollo Medical Operations Project

## ◆ EMU/EVA Suit

### ● Recommendations *cont'd*

- Develop a reliable Heads-Up Display (HUD) displaying consumable information, limited BIOMED data, and navigation on demand.
- The HUD primarily should be presenting the operational information that you need in an instant. If you want to see oxygen, you say “oxygen” and it appears.
  - Be careful not to increase the complexity of the system thereby reducing its reliability.



*Three astronauts on the Moon. Art by Pat Rawlings.*



# *Apollo Medical Operations Project*

## ◆ EMU/EVA Suit



### ● Recommendations

- **The lunar boot functioned well and does not need to be improved**
  - The boot was very comfortable; however, it was slippery on rocks or boulders:
    - Regolith had a high coefficient of friction.
    - There was not concern about ankle sprains or injuries with falls.



## ◆ EMU/EVA Suit

### ● Recommendations

- Debriefs imply loping was the most biomechanically efficient form of movement:
  - The metabolic cost was less with skipping than with walking. It took more time and was more difficult to walk. It was very comfortable in the 1/6 g environment.
  - Hills seemed steeper and tougher to climb on the lunar surface and loping could not be used.







# ***Apollo Medical Operations Project***

## ◆ **EMU/EVA Suit**

- Recommendations *cont'd*
  - The drink bag should have capability to contain a high energy liquid along with plain water.
  - Develop a better in-suit Urine Collection Device (UCD) that will work in 1/6 g.
  - The suit should be a low pressure (3.50 psia), single gas system.
  - Develop a system that prevents helmet fogging during heavy exertion.
  - Use a self-sealing pressure garment within the suit for puncture.

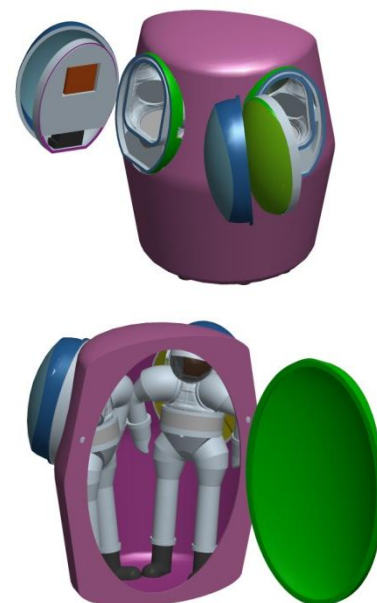
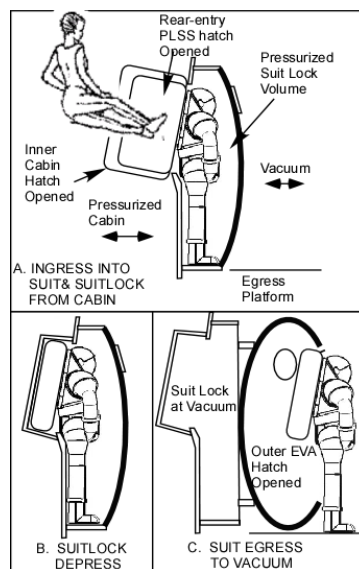


# Apollo Medical Operations Project

## ◆ EMU/EVA Suit

- Recommendations
  - **Protect the suit zipper function:**
    - The A7LB was a single zipper system
    - Lunar dust was difficult to clear from the zipper and impaired normal function on each subsequent lunar EVA

*Suit donning/doffing; dust management and pressure integrity on lunar surface may be facilitated by a rear-entry suit mated to a suit port*

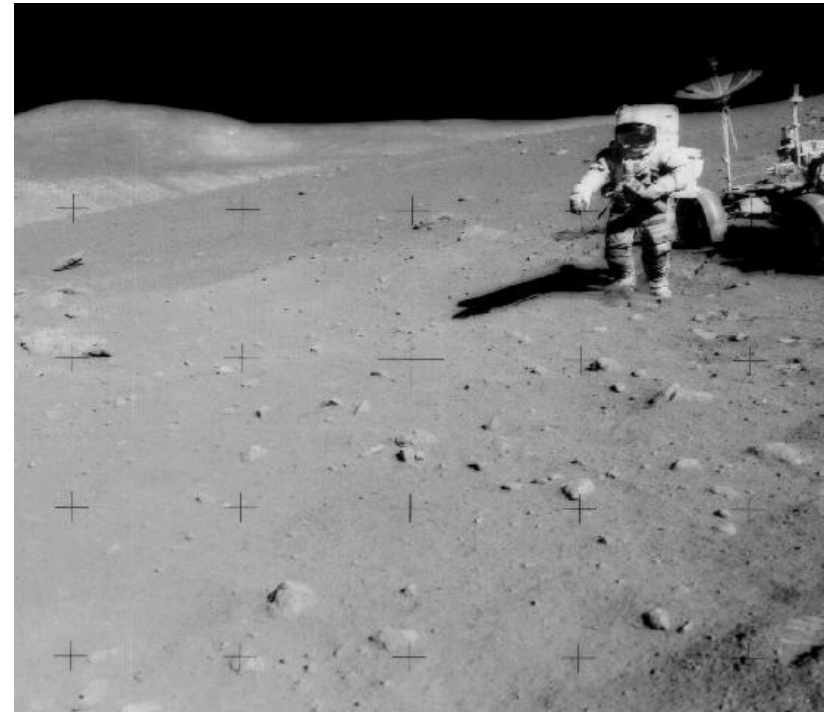




# ***Apollo Medical Operations Project***

## ◆ **Lunar Surface Operations**

- Regarding lunar EVA duration, crewmembers preferred to keep going as long as the system would allow.
  - It's time-consuming to break up the EVA with a repress in the vehicle or habitat, then depress to go out again, including performing many checks.







# ***Apollo Medical Operations Project***



## ♦ **Lunar Surface Operations**

- With extended ops on the moon, you should try to establish all the experiments in the first week or so, and then allow the crew to have a day to do R&R on the surface, just for the sake of being on the moon and recharging their batteries, so to speak.



# *Apollo Medical Operations Project*

## ◆ Lunar Surface Operations

- Schedule crew surface cycles of two LEVA days on and one day for maintenance, alternating crews throughout the week.
  - Be careful to guard against crewmembers overworking themselves.

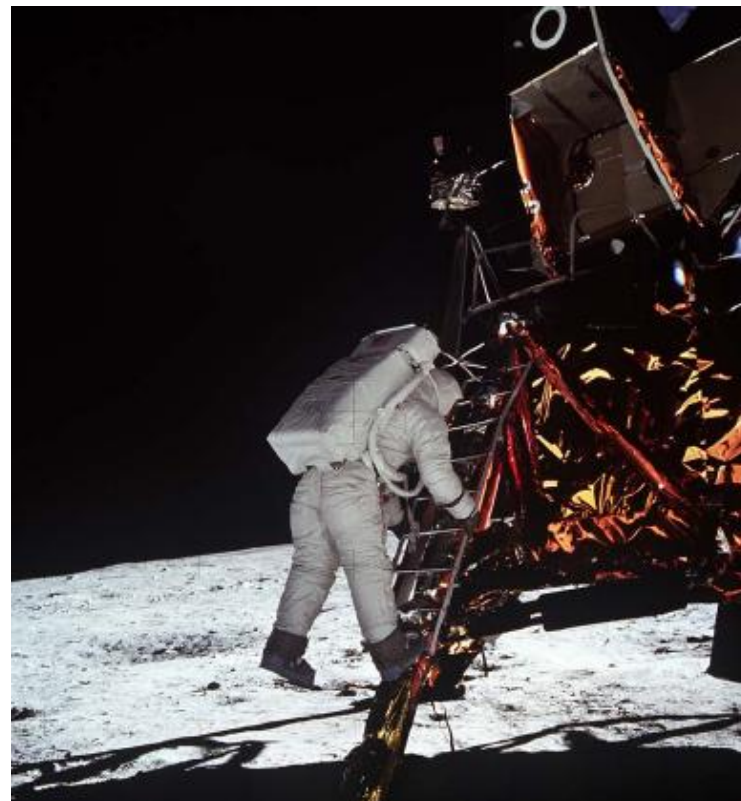


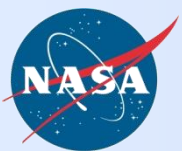


# *Apollo Medical Operations Project*

## ◆ Lunar Surface Operations

- The ladder did not cause a problem, although glove improvements would have decreased the concern of falling.
  - Rung width and height on LM were good.
  - Concern exists for falls if ladder height is increased.

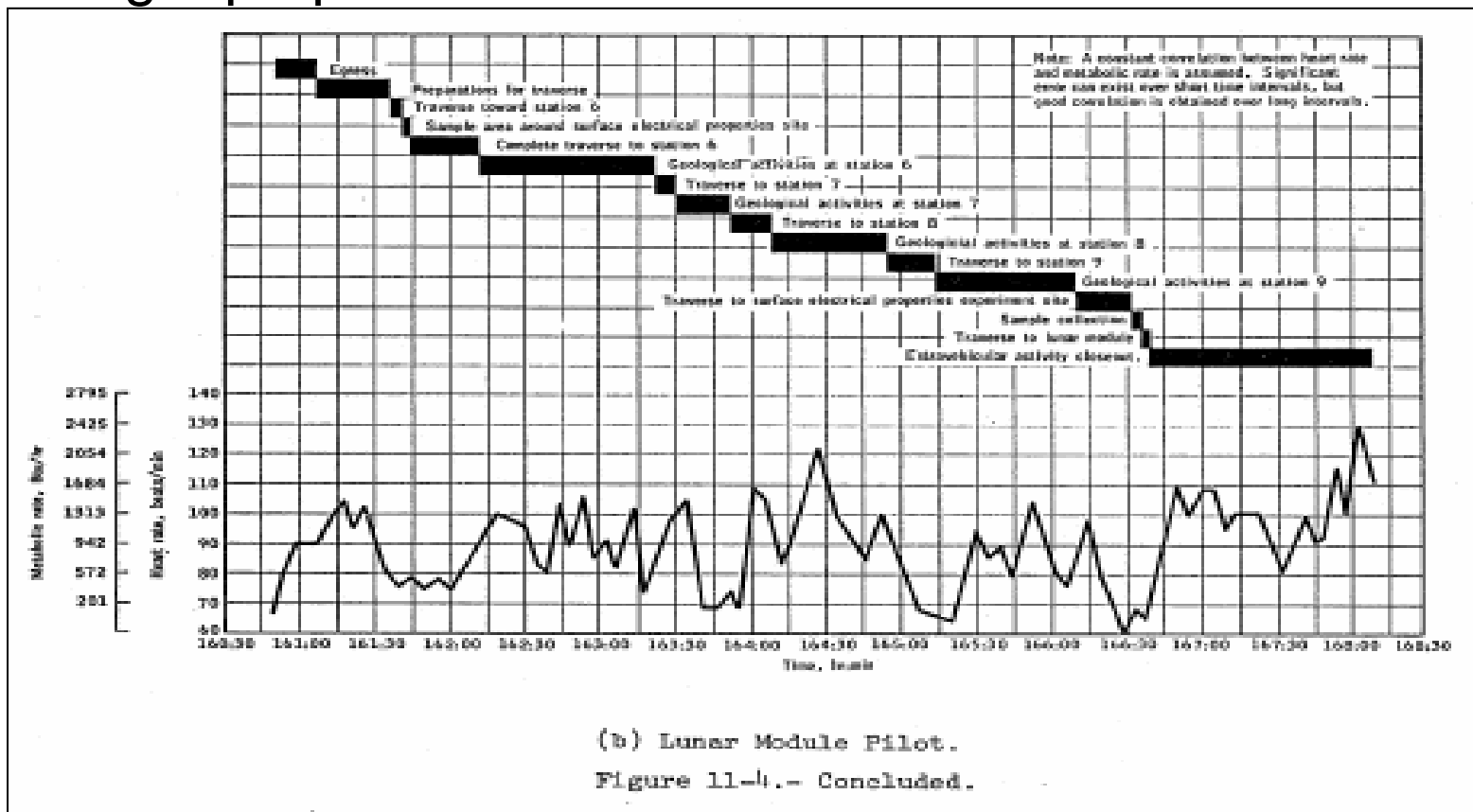




# Apollo Medical Operations Recommendations

## ◆ Lunar Surface Operations

- Metabolic expenditure: deconditioning or poor pre-flight preparation?





# Apollo Medical Operations Project



## ◆ Apollo Display Keyboard (DSKY)

- The DSKY was the method by which Apollo crewmembers communicated with the computers on board the Apollo Command and Lunar modules.





# Apollo Medical Operations Project

## ◆ Lunar Surface Operations

- The design of the hatch was the problem.
  - Crewmembers had difficulty maneuvering through the hatch. One of the main reasons was that the DSKY of the primary navigation and guidance was directly above the hatch.

*“That is one thing you would hit and you didn’t want to hit it very hard. You had to arch your back to the degree that you could and work your way through. Crewmembers had to help each other through. You need a hatch that is sized appropriately for an inflated 1/6 g pressure suit.”*
- The hatch should be designed where you can go straight.



# *Apollo Medical Operations Project*



## ◆ Lunar Surface Operations

- An airlock would be a good idea in the next lunar lander design.
  - An airlock may make ingress/egress easier and will also help with dust control.



# Apollo Medical Operations Project

## ♦ Lunar Surface Operations

AS17-146-22294



- Ambulating down slopes was difficult because it was hard to arch the back in the 3.75 psi pressure suit.
  - Side-stepping was actually used to ambulate down slopes more efficiently and safely.
- The steepest incline encountered was a 26-degree slope. If it were steeper, the crew would not have made an attempt.





# *Apollo Medical Operations Project*



## ◆ Lunar Surface Operations

- All sorts of ambiguities exist on the moon (e.g., slopes, terrains, sun shadows, bland environment).
  - “Reflective light in the shadows isn’t as evident as on earth. Craters did appear steeper visually. We knew we had to go down into that crater, so it gave us concern.”



# Apollo Medical Operations Project

## ◆ Lunar Surface Operations

- The pre-flight EVA training program prepared you for lunar EVA.
  - The POGO and centrifuge training were beneficial. There is no special training needed for 1/6 g EVAs.
    - Adaptation occurs quickly regardless.





# ***Apollo Medical Operations Project***



## ♦ **Lunar Surface Operations**

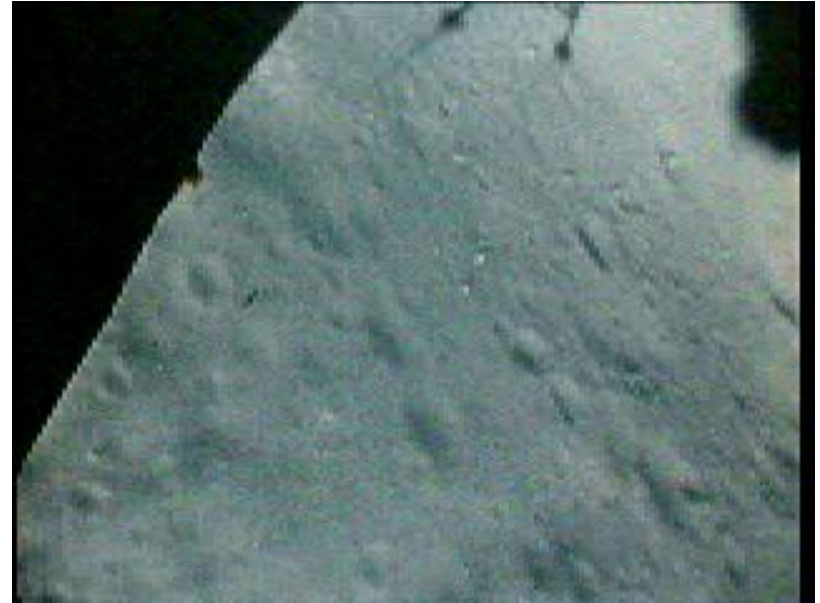
- Falls were not uncommon:
  - Crews cited rocks, equipment, terrain features, suit CG, & fatigue all contributed to falls.
  - Returning to upright posture was met with varying degrees of difficulty.
  - Crewmembers felt they were “well protected” in the suit.



# ***Apollo Medical Operations Project***

## ◆ **Lunar Surface Operations**

- Crews generally felt a little “wobbly” upon stepping on the moon.
  - Coordination seemed to improve steadily during first couple of hours on the surface.
- Crews denied problems with spatial disorientation on lunar landing.

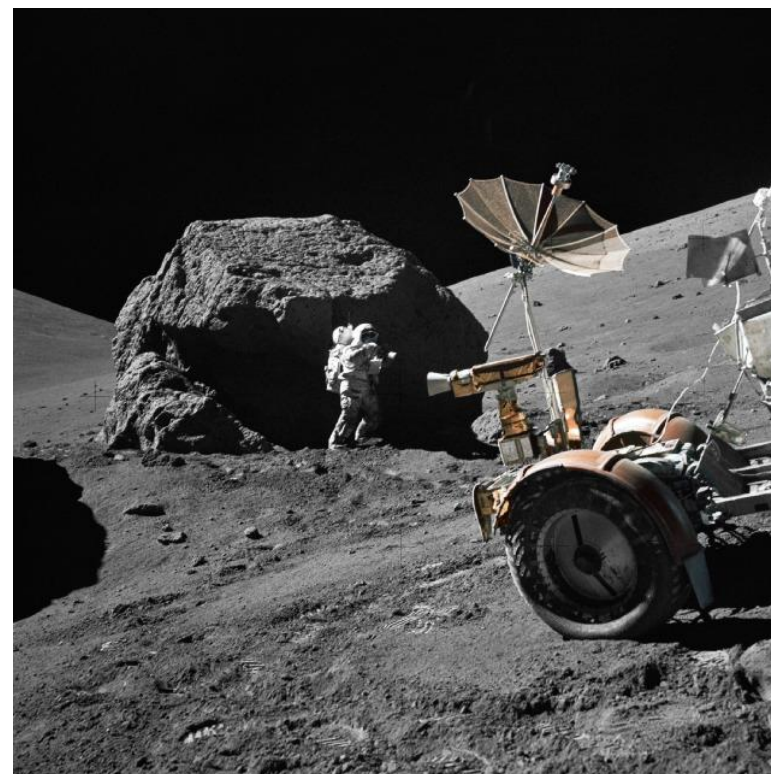




# Apollo Medical Operations Project

## ♦ Lunar Surface Operations *cont'd*

- Risk factors for injuries identified:
  - Limit navigation into craters to  $< 20\text{-}26^\circ$  slope
  - Rover activities
    - CDR
    - LMP
  - Falling from a height:
    - Ladder
    - Rim of a crater



*Apollo 17 LMP H. Schmitt near North Massif at Taurus-Littrow*





# *Apollo Medical Operations Project*

## ◆ 144-hr depress scenario



*RAS and Neil Armstrong, Atlanta, May 2012*



## ◆ Lunar Surface Operations

- Recommendations

- Schedule crews for two Lunar EVA days on and one day for maintenance, alternating crews throughout the week.
- There is no special training needed for 1/6g EVAs other than a familiarization session.
- **Surface activities can begin once operationally feasible.**



## ◆ Lunar Surface Operations

- Recommendations *cont'd*
  - Ladder rung height and width on the Lunar Module (LM) were good but the glove did not allow adequate grip for safety.
  - **Ensure adequate water and food are available before and during lunar EVA.**
  - Lunar EVA should be performed as one continuous event.
  - Plan the operations on the surface so that you protect the crews from themselves.
  - With extended ops on the moon, establish all the experiments in the first week.





## ◆ Lunar Surface Operations



- Recommendations *cont'd*
  - A robot should perform routine, systematic, repetitive, menial tasks (may help prevent repetitive use injuries).
  - The Rover should have the ability to recharge your suit.
  - Crews requested that an automatic position determination device be available to aid navigation on the lunar surface.



## ◆ Lunar Surface Operations

- *“Lunar dust particles floated everywhere in the LM upon return to  $\mu\text{g}$ :”*
  - Dust particles got into crew members eyes, nose, & chest.
  - This prompted crews to keep helmets on before docking with CSM.
  - Dust did not appear to be filtered from the environment through ventilation/LiOH system.



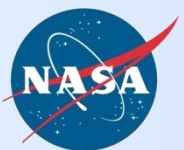
# ***Apollo Medical Operations Project***

## ◆ **Lunar Surface Operations**

- Dust is slowly cleared in the cabin by lithium hydroxide.
  - Dust is very abrasive and there are jagged fragments. The dust on the surface was a problem because it covered all your gear, visors, etc.



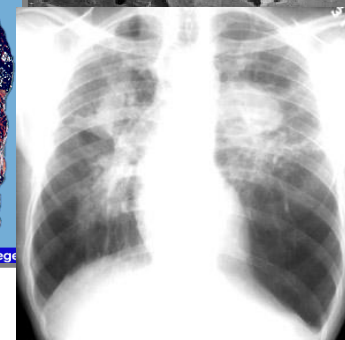
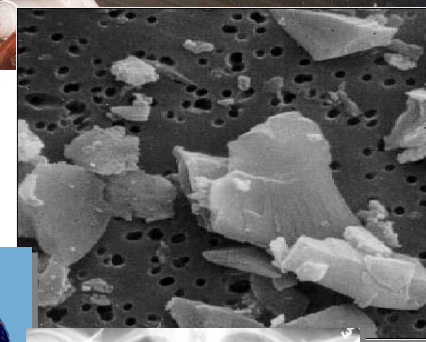
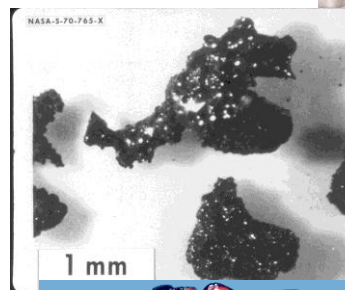
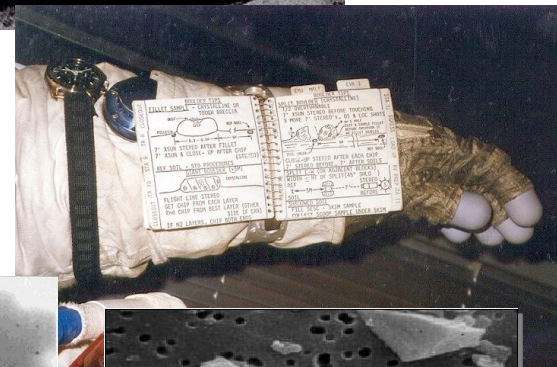
*Apollo 17 CDR G. Cernan in the LM following EVA #2*



# Lunar Dust

## Why are we concerned?

- Dust particles **levitated** at the lunar terminator, perhaps due to **polarity** changes (Criswell '72). **0.16 G** at lunar surface, where there is a layer of fine particles that are easily disturbed and placed into suspension. These **particles cling to all surfaces & pose serious challenges for the utility of construction equipment, air locks, and all exposed surfaces** (Slane '94)
- After lunar EVA crewmen & samples they had collected were covered with fine lunar material. Despite attempts at clean-up & packaging in the LM, transfer of crew & materials back to the CM resulted in **contamination of the CM atmosphere** (Brady et. al, 1975)
- Apollo astronauts were not in the lunar environment long enough to develop the clinically significant, dust-related symptoms. However, during upcoming missions, crews will be on the Moon for months at a time.
- **Properties**
  - Size, shape, impacts with space, not terrestrial weathering, metal content
  - Possible reactivity- volatiles, solar protons, unsatisfied chemical bonds- passivation rate?







# Apollo Medical Operations Project

## ◆ Lunar Surface Operations

- To ensure operational success and optimize performance of the crews:
  - **Allow adequate time to practice mission activities in a variety of environments including good analogs that allow preparation for off-nominal events.**



*Apollo 16 Geological field training in New Mexico*



*Apollo 12 Lunar Lander Training Vehicle (LLTV) Ellington Field*



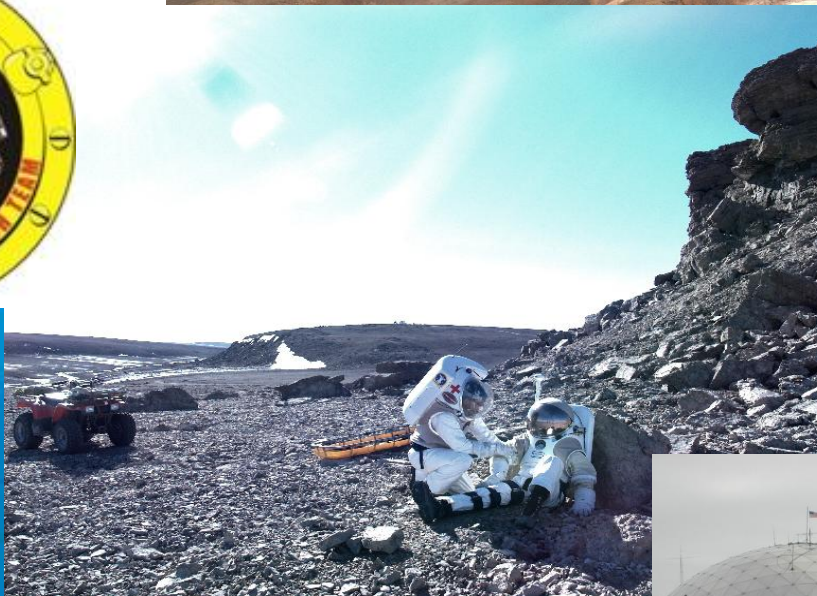
*Apollo 17 Lunar Surface Activity training at JSC*



# Apollo Medical Operations Project

## ◆ Analog environments

- Remote location, not easily accessible
- Operationally focused multiple “E” several days



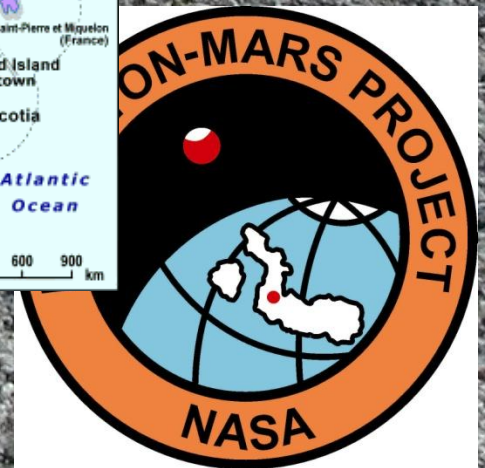
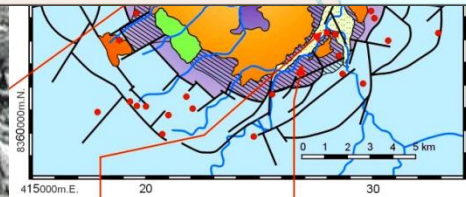
*Lunar Medical Contingency Simulation,  
Haughton-Mars Crater, Devon Island, Aug. 2006*





# Haughton Crater, Devon Island

“The  
with







# ***Moon/Mars Analog***

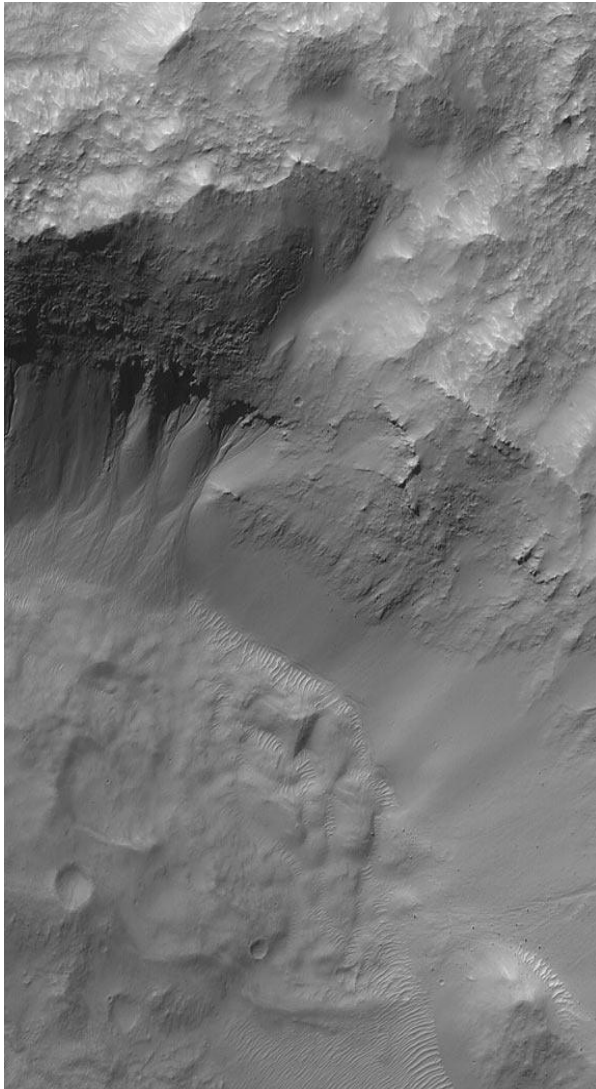


Photo courtesy of NASA-JPL



Photo courtesy of HMP 2006/R. Scheuring

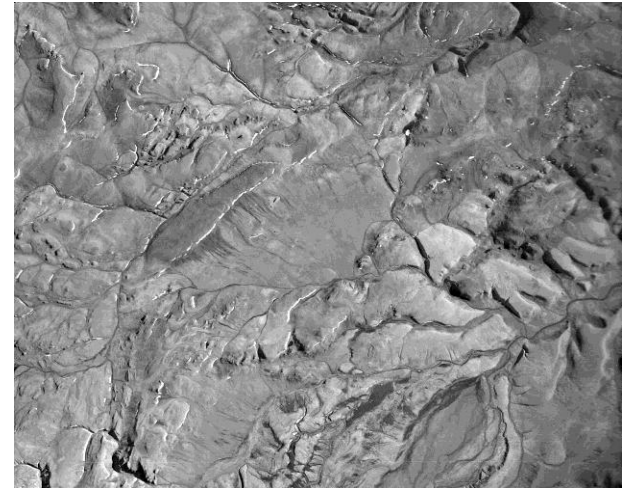


Photo courtesy of HMP 2006/P.Lee

13 August 2013

R.A. Scheuring 3-9769





## 3rd Party Assisted Rescue on Sloped Terrain (haul from top)



Used with permission. Chappell, S. and  
Analysis & Design," 36th International

13 August 2013

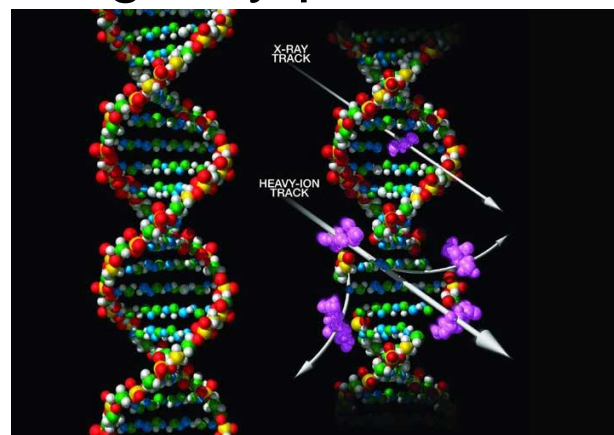
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# Apollo Medical Operations Project

## ◆ Radiation

- For radiation protection on the surface, creating a trench with shovels or explosives would be adequate to protect the crew short term:
  - Important to cover the trench quickly.
  - A PRD in the suit will let you know how well you have done.
  - The rover should be equipped with a radiation shield.
- Apollo 12 did not have any contingency plan for an SPE on the surface.





## ◆ **Radiation**

- **Recommendations:**
  - Vehicle should have active radiation detectors with alarms that sound when the dose gets too high for safety.
  - A Passive Radiation Dosimeter (PRD) is a requirement for all crewmembers:
    - Design it into the suit garments.
  - The rover should be equipped with a radiation shield.
  - Radiation protectants should be made available to the crewmembers.
  - Create a trench with shovels or explosives to protect the crew short term in the event of a Solar Particle Event (SPE).





# Apollo Medical Operations Project

## ◆ Environmental Impacts

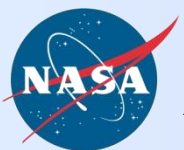
### ● Recommendations *cont'd*

- Thermal protective clothing or equipment should be available onboard.
- Drinking water should be available during sleep periods.
- Lunar Surface Ascent Module (LSAM) windows should be designed to see only what is necessary for landing or rendezvous with IR protection or both.



*Apollo 13 CDR Jim Lovell in the Aquarius LM*





# Apollo Medical Operations Project

## ◆ Discussion

- *Res ipsa loquitur*
- 107 recommendations provided for consideration in the exploration architecture
- Implementation:
  - **EMU/EVA Suit**- EPSP & EVA SIG of CxP->D&C Doc, EVA Systems SRD, IRD
  - **Lunar Surface Ops**- Med Ops CONOPS Doc, Hatch-HSIR, CEV Cockpit RD, EPSP (Fluid requirement), GGRnC/CSCD
  - **In-Flight Illnesses**- MORD, Med Ops section of CONOPS, SFHS Vol I, HSIR
  - **Meds/Medical kits**- Medical checklist
  - **Environmental**- Toilet-HSIR, Hot water-HSIR, Thermal protection-HSIR, CEV Cockpit RD, CEV/LSAM SRD
  - **BHP**- Med Ops CONOPS, GGRnC/CSCD
  - **Exercise**- HSIR, Med Ops CONOPS, GGRnC
  - **Food/Nutrition**- HSIR
  - **Launch, Landing & Recovery**- HSIR, Med Ops CONOPS, CARD, Cockpit RD
  - **Surgeon-Crew Interaction**- PMC-HSIR, Cockpit RD



# *Apollo Medical Operations Project*



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